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ABSTRACT

This guide describes six bubble activities for developing a variety of process skills in grades 5-9. Activities included are: (1) "Bubble Technology"; (2) "Comparing Bubble Solutions"; (3) "The Chemistry of Bigger Bubbles"; (4) "Bernoulli's Bubbles"; (5) "Predict-a-Pop" for studying interference; and (6) "Longer-lasting Bubbles." In each activity, time periods for teacher preparation and classroom activity, materials, preparation procedures, observations, discussion, experiments and further research are described with necessary worksheets. Three resource books are listed. Summary outlines of the six activities are provided. (YP)

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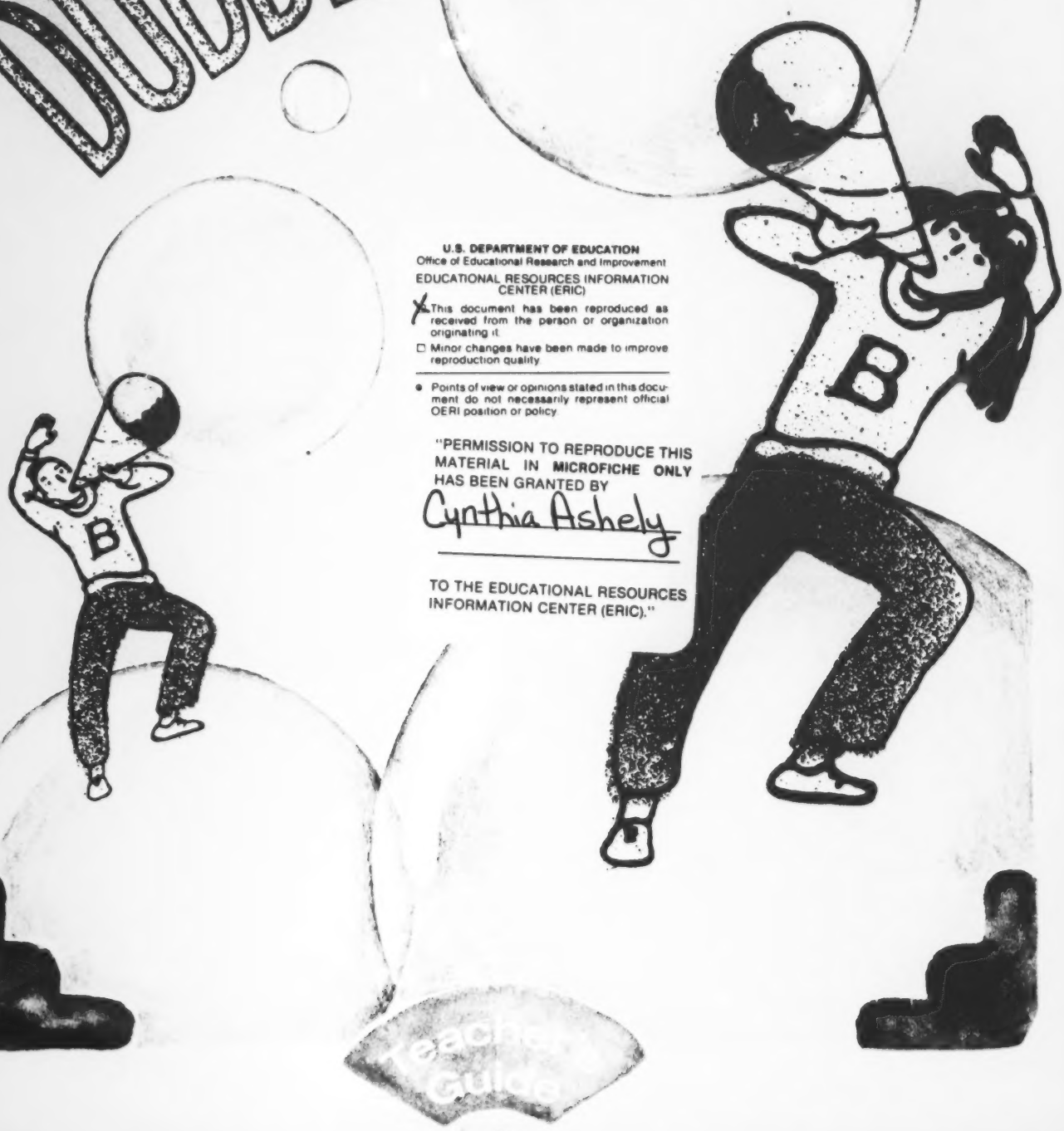

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Teacher's Guide

BUBBLE-OLOGY

Teacher's Guide

Grades 5–9

Skills

Observing, Measuring and Recording Data, Experimenting,
Classifying, Drawing Conclusions, Controlling Variables,
Calculating Averages, Graphing Results

Themes

Technology, Engineering, Chemical Composition, Substances, Properties,
Surface Tension, Hygroscopicity, Optimum Amount,
Bernoulli's Principle, Aerodynamics, Pressure,
Patterns, Light and Color, Interference,
Air Currents, Evaporation, Environments

Time

From eight to ten 45- to 60-minute sessions

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Great Explorations in Math and Science (GEMS)
Lawrence Hall of Science
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COMMENTS WELCOME

Great Explorations in Math and Science (GEMS) is an ongoing curriculum development project. GEMS Guides are revised periodically, to incorporate teacher comments and new approaches. We welcome your criticisms, suggestions, helpful hints, and any anecdotes about your experience presenting GEMS activities. Your suggestions will be reviewed each time a GEMS Guide is revised. Please send your comments to: GEMS Revisions, c/o Lawrence Hall of Science, University of California, Berkeley, CA 94720.

Great Explorations in Math and Science (GEMS) Program

The Lawrence Hall of Science (LHS) is a public science center on the University of California at Berkeley campus. LHS offers a full program of activities for the public, including films, lectures, special events, exhibits, classes, and workshops. LHS is also a center for teacher training and curriculum research and development.

Over the years, LHS staff have developed a number of activities, assembly programs, classes, and exhibits. These programs have proven to be successful at the Hall and should be useful to other science centers, museums, schools, and community groups. A grant from the A. W. Mellon Foundation has made possible the publication of these activities under the "Great Explorations in Math and Science" (GEMS) title.

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Introduction

Watching a soapy puddle turn into a beautiful, fragile, multi-colored sphere is always a fascinating experience. This fascination accounts for the universal and eager interest in bubbles.

Bubbles are not only captivating, colorful, and fun to make, they are also excellent demonstrations of scientific phenomena. Some of the topics introduced in this booklet are:

- light and color
- aerodynamics
- chemical composition
- surface tension
- technology

Your students will also have an opportunity to develop a variety of skills useful for continued study in science and for daily life. These skills include:

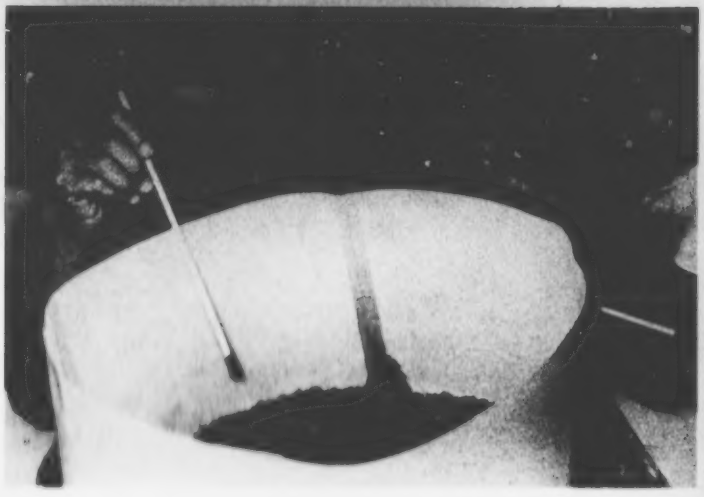
- making observations
- measuring and recording data
- experimenting
- calculating averages
- graphing results
- making inferences
- drawing conclusions

A few things to know before you get started:

Each activity introduces concepts and skills that build upon what students learn in previous activities. The early activities allow students to blow bubbles to their hearts' content. Giving free rein to this very natural impulse helps pave the way for later activities, which require that students blow bubbles and then *not* pop them.

Because bubbles are so interesting and exciting, some teachers prefer to present activities over a longer time period, rather than concentrating them in a one or two week period.

Bubble-ology is a motivating and powerful introduction to the process and substance of science... and besides, it's good, clean, fun. So roll up your sleeves and get started!



Time Frame

Activity 1: Bubble Technology
Teacher Preparation: 20 minutes
Classroom Activity: one or two 45-minute sessions

Activity 2: Comparing Bubble Solutions
Teacher Preparation: 20 minutes
Classroom Activity: one 40- to 60-minute session

Activity 3: The Chemistry of Bigger Bubbles
Teacher Preparation: 15 minutes
Classroom Activity: two 45-minute sessions

Activity 4: Bernoulli's Bubbles
Teacher Preparation: 15 minutes
Classroom Activity: one 45-minute session

Activity 5: Predict-A-Pop
Teacher Preparation: 15 minutes
Classroom Activity: one or two 45-minute sessions

Activity 6: Longer Lasting Bubbles
Teacher Preparation: 20 minutes
Classroom Activity: two 45- to 60-minute sessions

Activity 1: Bubble Technology

Introduction

Can you blow a bubble with a pair of scissors, a piece of paper, or a rubber band? In this activity, your students experiment to discover what objects can be used to blow bubbles, which make little bubbles, and which make big bubbles. Then they use the information they've gathered to design and draw bubble-makers for specialized uses. This activity introduces students to the process of technology and allows them to get some of the bubble blowing out of their systems—something you'll appreciate during later activities!

What You Need

For preparation and cleanup:

- ☐ newspapers to cover tables
- ☐ 8 oz. (240 ml) dishwashing liquid
- ☐ water
- ☐ measuring cup or graduated cylinder
- ☐ eyedropper
- ☐ 1 one-gallon container for mixing bubble solution
- ☐ glycerin (optional)

For the class:

- ☐ at least ten different materials to use for bubble-makers, such as: strainer, small tin cans, protractors, paper, mason jar lids, string, drinking straws, tea ball, rubber stoppers with holes, flower pots, funnels, eyedroppers, turkey basters, rubber tubing, paper cups, styrofoam cups, various gauges of screen, different sized washers, rubber bands, toilet-tissue and paper-towel rolls, aluminum foil, wire of different gauges, springs, scissors, tubes of any kind, oatmeal box, and anything else you think appropriate.

Consider asking students to bring in possible bubble-maker materials from home.

For each group of 3–4 students:

- ☐ 1 wide-mouthed, flat-bottomed pan (such as a metal pie pan, dish pan, or other container suitable for holding bubble solution)

Getting Ready

1. Prepare one gallon of bubble solution:
   1 cup (240 ml) dishwashing liquid
   50–60 drops glycerin (optional)
   1 gallon water (3.8 liters)

2. Cover tables with newspapers.

3. Fill containers with about 2 cups of bubble solution and set them on tables.

4. Place all bubble-maker materials you have been able to collect on a central table.

5. Clear two other tables or surfaces on which students will place bubble-maker materials after they've been tested—one table for those that work, and one for those that do not.

Presenting The Challenge

1. Ask: "Who has blown soap bubbles before?" "What did you use to blow the bubbles?" Explain that the challenge during this session is to discover what materials or objects can be used to blow bubbles and what kinds of bubbles these materials make.

2. Point out the materials to experiment with to the students. Tell them that they should each test 8 to 10 different materials.

3. After students test a material, they should place it on one of two tables—one for materials that succeed in making bubbles, and one for materials that do not. Point out that any student may try materials from the "don't work" table over again. If this new attempt succeeds, that material should be moved to the table for materials that work.

4. Write "small" on one side of the board and "large" on the opposite side. Ask the students to classify each material they test as to whether it makes large or small bubbles. Have them write the names of the objects on the board, in order according to the bubble size they produce.

Experimenting

As students experiment, circulate among them suggesting questions to investigate, such as:

- What would happen if you changed the shape of the wire?
- Does the length of the tube make a difference?
- Which kind of cup works better—paper or styrofoam?
- Can you think of a way to use this paper towel to blow a bubble?

Drawing Conclusions

1. Gather the students around the chalkboard. Ask:
   - "What's the same about all working bubble-makers?"
   - "What objects didn't work?"
   - "What were these objects lacking?"
   - "What strategies did you use to make something work as a bubble-maker?"

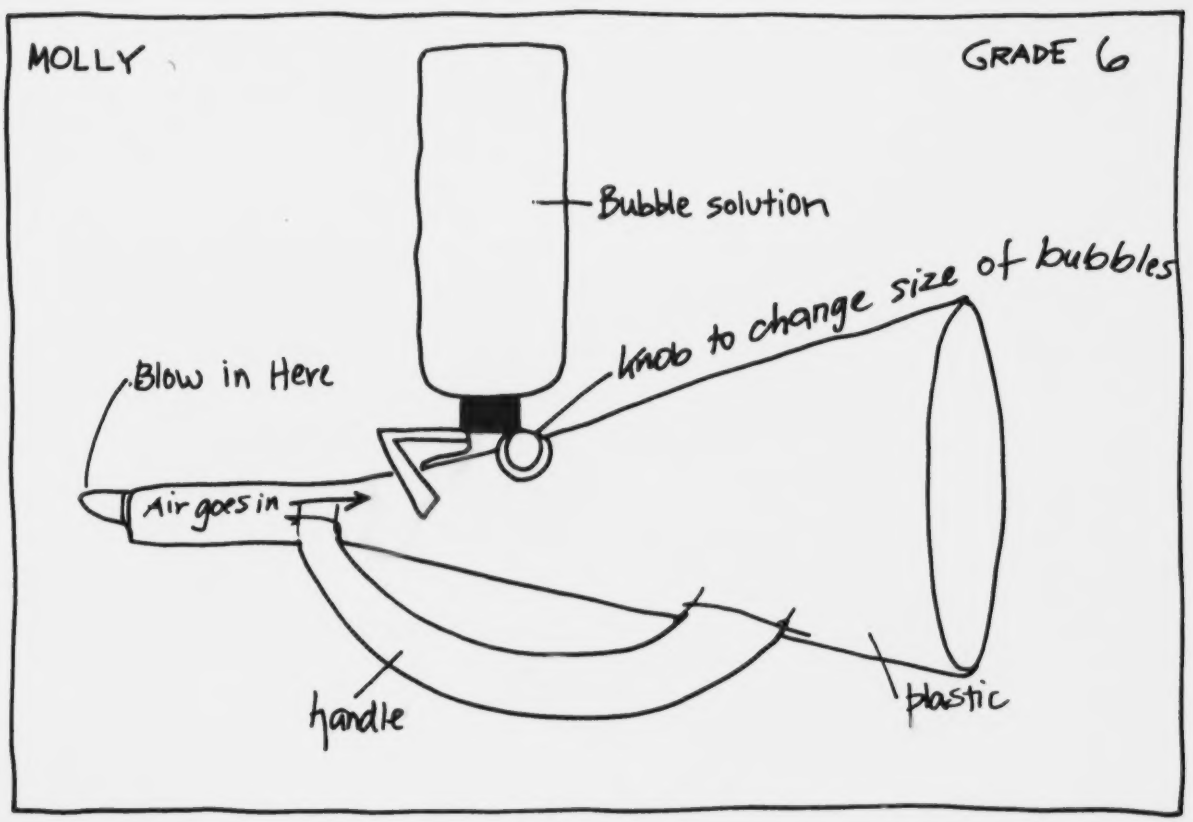
2. As a group, go over the list of bubble-makers according to bubble size. What characteristics did makers of smaller bubbles share? Makers of larger bubbles?

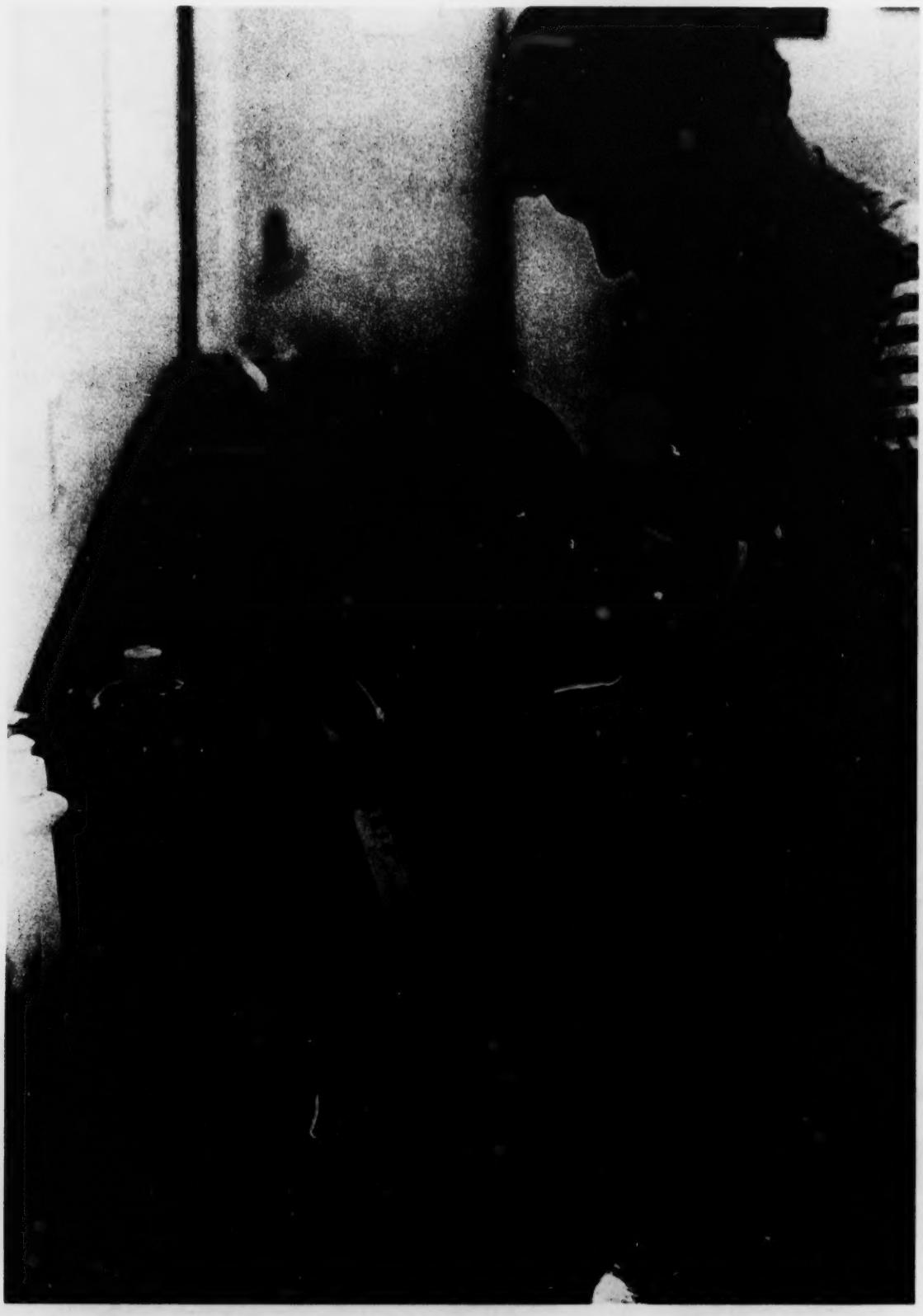
3. Explain that ***technology*** involves the use of science to create something practical. Point out to your students that they have just conducted a series of experiments to gather information about bubble-blowing tools. Now you'd like them to use that information to create a practical application of science. Creating practical applications of science is what engineers do.

Give your students a homework challenge: to create imaginative drawings of bubble-makers for specialized uses. For example, a bubble-maker that: creates foam; doesn't need to be dipped into a soap solution; makes large, detachable bubbles; or other creative ideas your students might suggest.

Going Further

Have your students combine materials to make more complicated bubble-making contraptions.





10 *Activity 2*

Activity 2: Comparing Bubble Solutions

Introduction

Challenge your students to determine which brand of dishwashing liquid will make the biggest bubble. This activity presents your students with a way to quantify how well a soap solution forms bubbles. It also introduces the scientific concept of a ***fair test.***

What You Need

For preparation and cleanup:

- ☐ 8 oz. (240 ml) of three different brands of dishwashing liquid (include one cheap and one expensive)
- ☐ water
- ☐ 1 measuring cup or graduated cylinder
- ☐ 1 eyedropper
- ☐ 3 one-gallon containers for mixing bubble solution
- ☐ 1 roll of masking tape
- ☐ paper towels
- ☐ 2 cups vinegar
- ☐ glycerin (optional)
- ☐ squeegie (optional)

For each pair of students:

- ☐ 1 meter or yard stick
- ☐ 2 plastic drinking straws
- ☐ 1 one-pint container (such as a cottage cheese container) for holding bubble solution
- ☐ 1 "Bubble Solutions" data sheet (master included, page 16)
- ☐ 1 pencil
- ☐ 1 table, counter, desk, or board about 30" (75 cm) in diameter
- ☐ calculator (optional)

Getting Ready

1. Make one copy of the "Bubble Solutions" data sheet for each pair of students.

2. Label one of the large and a third of the small containers with the name of each dishwashing liquid.

3. Prepare three different bubble solutions (one bubble solution from each brand of liquid) in the three large containers:

   1 cup (240 ml) dishwashing liquid
   50–60 drops glycerin (optional)
   1 gallon water (3.8 liters)

4. Pour about one cup of the appropriate solution into each of the small, labeled containers.

5. For each pair of students, set up one test station on a flat surface, about 30" (75 cm) in diameter. Place a small container of one type of solution and a meter stick at each station.

Introducing the Activity

1. Explain that the object of this session is to compare brands of dishwashing liquid to find out which solution makes the biggest bubbles. Ask the students for their ideas on how they might design an experiment to make this comparison.

2. After several ideas for experiments have been shared, explain, if it has not already become clear, that in order to compare dishwashing liquids as to bubble size, a standard method to measure the bubbles is needed. Demonstrate the following procedure for measuring bubbles:

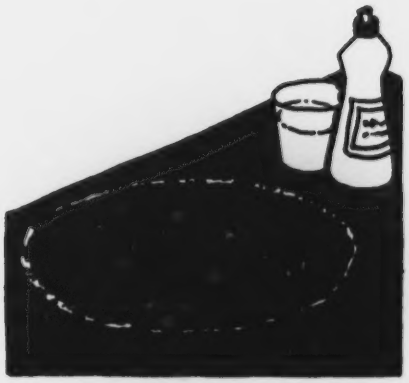
   a. Pour some soap solution on the surface of the table, and use your hand to wet an area about 18" (45 cm) in diameter.

   b. Dip a straw into the solution in the container.

c. With the straw just touching the soapy surface of the table, gently blow through the straw to form a bubble dome, and continue blowing until it pops. Take more than one breath if necessary.

d. With a meter stick, show the students how to measure the inside diameter of the ring of soap suds left by the bubble dome.

Tell your students that using this method provides one standard way to measure the size of a bubble.



Experimenting

1. Have the students work in pairs to measure bubbles from all three solutions. Suggest that they alternate blowing bubbles to reduce the chance of hyperventilation—students have been known to blow big bubbles! Instruct each pair of students to measure four bubbles per brand and average their results. Then have them move on to a solution with another brand of soap and again measure four bubbles.

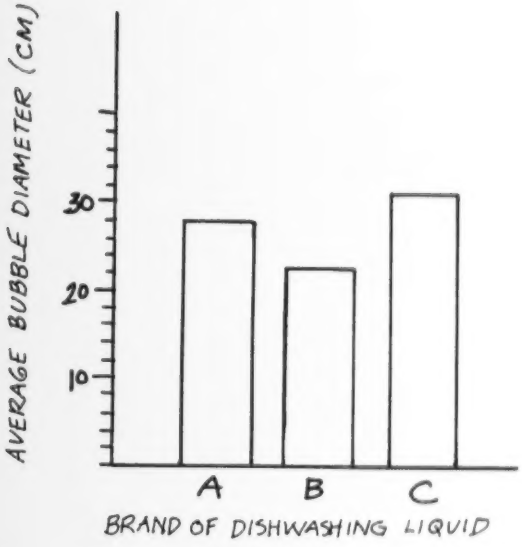
2. As your students start to experiment, they will come to you with questions such as: "He popped my bubble. Does that bubble have to count?" "This bubble is oblong. How do I measure its diameter?" You may also notice students who won't record the diameter of smaller bubbles. Respond by saying that they are the scientists. It's up to them to decide what is fair. Whatever they decide to do, they'll need to make sure all three brands are treated in the same way. Otherwise one brand of soap will be given an unfair advantage.

If your students have difficulty calculating averages, use the following method to analyze the results:

—Have your students write all of their bubble dome measurements on the board.

—For each brand, count the number of bubble domes that were larger than a given diameter (e.g., 30 cm).

—Use this number to compare brands and determine which brand made bigger bubbles.



Analyzing Results

1. Reconvene the class around the chalkboard. Write the names of the dishwashing liquids across the top of the board, and record the students' averages under each column. Ask your students to calculate the grand average for each brand of soap solution.

2. As a group, make a bar chart on the chalkboard, comparing the average bubble diameter for each soap brand. Rank the brands of soap from biggest to smallest bubble-maker.

3. Ask the students if this has been a "fair test." In testing the three brands of soap solution: Was the same amount of bubble solution used each time? Were all bubbles measured in the same way? Was there anything else that might have affected the results?

Explain that the factors that change from one time a bubble is blown to the next are called ***variables.*** Point out that in a fair test, all variables are kept the same or "controlled" except for the ***test variable***. Scientists call this a ***controlled experiment***. Ask what they think the test variable was in this experiment. [The brand of soap.]

4. See if your students have any ideas why certain dishwashing liquids make bigger bubbles than others [e.g. the proportion of soap to water, the amount and type of additives used, etc.]. Tell them that in the next activity, "The Chemistry of Bigger Bubbles," they will investigate *why* some substances are better bubble-makers than others.

Cleanup

To clean soapy tables: first use a squeegie or paper towels to remove excess bubble solution. **Do not add water.** Then sprinkle vinegar on the area to cut the soap film. Wipe dry with paper towels. Repeat once more if surface still retains soap film.

Going Further

1. Challenge your students to devise ways to test additional bubble qualities (e.g. life span, durability).

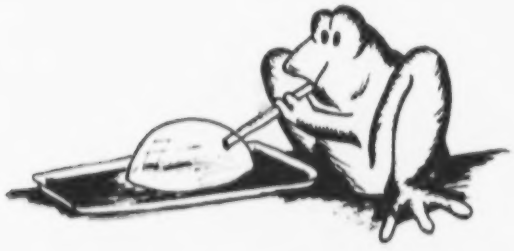
2. Ask your students how they might design an experiment that tests the dishwashing properties of various brands of dishwashing liquid.

3. Show your students how to express their results as the average *volume* of a bubble dome, rather than an average diameter. Assume that a bubble dome is half of a sphere. Determine the length of the bubble dome radius (r), and calculate the volume (v) of a sphere:

$$v = 4/3\ \pi\ r^3$$

Then divide by two to determine the volume of half of a sphere.

Make further use of the formula for the volume of a sphere by having the class calculate their own lung volumes. Instruct each student to blow a bubble dome with three lungfuls of air. Have them determine the volume of that bubble dome and divide by three to find their average lung volume.



BUBBLE SOLUTIONS

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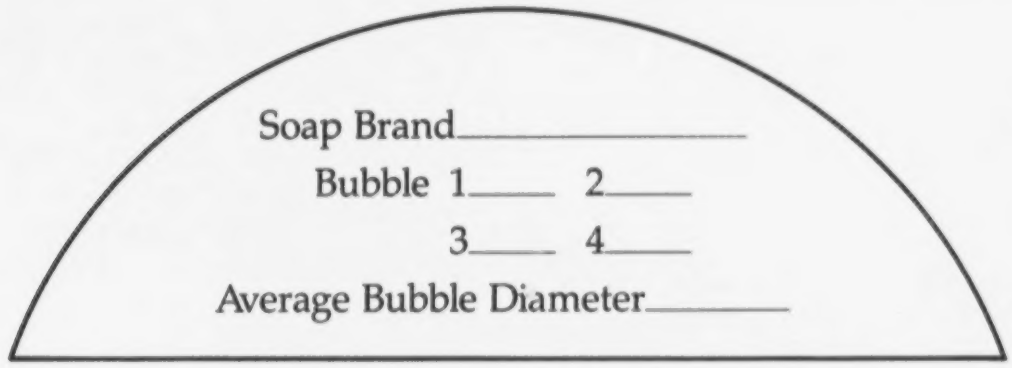
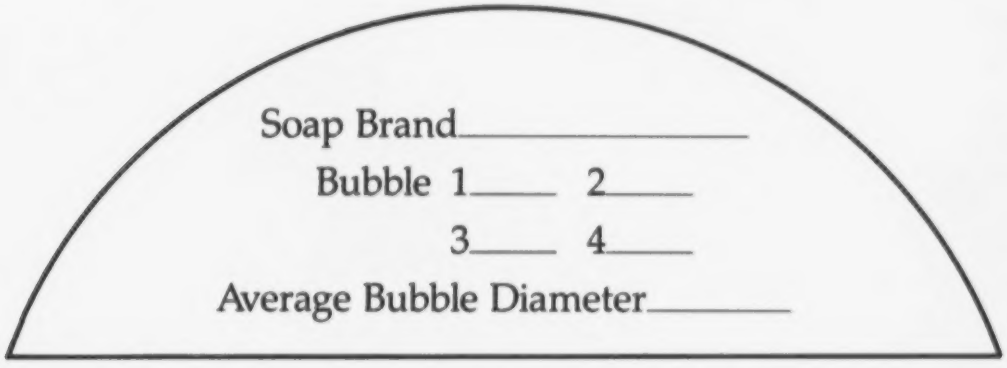
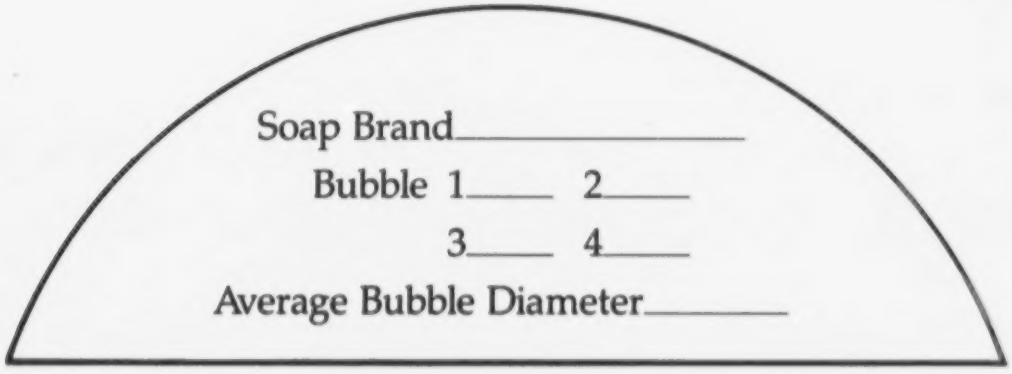






WHICH SOAP BRAND HAD THE BIGGEST AVERAGE BUBBLE DIAMETER?

Activity 3: The Chemistry of Bigger Bubbles

Introduction

Why do some dishwashing liquids make bigger bubbles than others? Why does cream form bubbles when it is whipped, while milk does not? An enormous variety of natural substances form bubbles. Sea foam is formed by the agitation of phosphates (like those in soaps) released by decomposing kelp. Egg whites form hundreds of tiny bubbles when beaten. In each case, the formation of bubbles depends on the ***chemical composition*** of the substance.

This activity introduces your students to some of the properties of bubble-making substances. The students observe how soap affects the ***surface tension*** of water and investigate the role of evaporation in bubble formation, as they test the effect of different amounts of glycerin on the size of bubbles.

What You Need

For preparation and cleanup:

- ☐ 8 oz. (240 ml) dishwashing liquid
- ☐ water
- ☐ measuring cup or graduated cylinder
- ☐ 1 one-gallon container for mixing bubble solution
- ☐ 1 roll of masking tape
- ☐ paper towels
- ☐ 2 cups vinegar
- ☐ 1 squeegie (optional)

For the class:

- ☐ several ounces of glycerin
- ☐ several eyedroppers
- ☐ several measuring cups
- ☐ several calculators (optional)
- ☐ chalkboard
- ☐ chalk

For each pair of students:

- ☐ 1 meter or yard stick
- ☐ 2 plastic drinking straws
- ☐ 1 one-pint container (such as a cottage cheese container) for holding bubble solution
- ☐ 1 "Experimenting with Glycerin" data sheet (master included, page 26)
- ☐ 1 graphing sheet (master included, page 27)
- ☐ 1 pencil
- ☐ 1 table, counter, desk, or board about 30" (75 cm) in diameter

For the demonstration:

- ☐ 1 tall, clear, drinking glass
- ☐ water
- ☐ water pitcher
- ☐ 1 eyedropper
- ☐ dishwashing soap (just 1 drop)

Getting Ready

1. Make one copy of the "Experimenting with Glycerin" data sheet and of the graphing sheet for each pair of students.

2. Prepare a gallon of bubble solution without glycerin:

   1 cup (240 ml) dishwashing liquid
   1 gallon water (3.8 liters)

3. Clear one flat surface, about 30" (75 cm) in diameter, for each pair of students.

4. Place the demonstration materials on a table or desk.

5. Label eight pint containers "A" through "H." Fill all eight containers with one cup of bubble solution made with no glycerin. Leave container "A" without glycerin. Add 10 drops of glycerin to container "B," 20 drops to container "C," and so on through container "H," which will have 70 drops of glycerin. Hold the eyedropper **vertically** in order to help reduce variation in size of drops.

6. Place these containers of bubble solution and all other materials on a centrally located table.

GO!

Observing Surface Tension

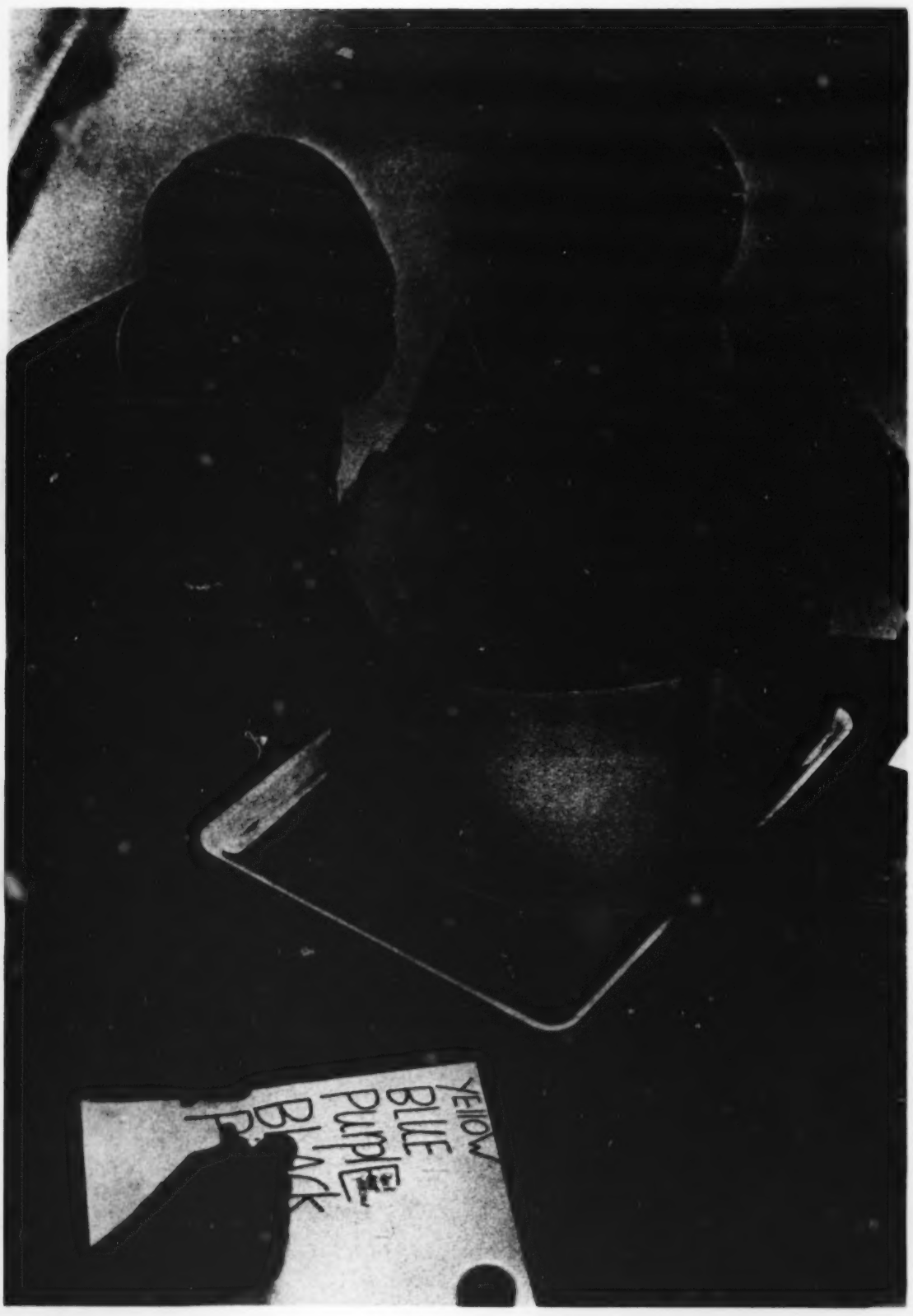
1. Ask your students what substances they can think of that form bubbles. Point out that some substances, such as water, do form bubbles, but these bubbles disappear almost as quickly as they are formed.

2. Perform the following demonstration to explain why pure water bubbles don't last:

- Gather the group around the demonstration table. Have them squat down so their eye level is closer to the level of the table.
- Fill a glass to the top with water. Keep adding water, drop by drop, until you think the glass will overflow. Then add a few more drops. If you are careful, you'll be able to add water until the surface of the water is actually higher than the glass.
- Ask students if they can see that the water behaves as if it were covered with a skin. Explain that this effect is called ***surface tension***. Water molecules at the surface of water are more attracted to each other than to the air; it is as if they stick together. This "stickiness" causes surface tension. Surface tension keeps water from spilling and discourages the formation of bubbles. When bubbles do form, they are short-lived.

If you have an extra twenty minutes and access to enough eyedroppers for each student, consider replacing this teacher demonstration with a hands-on student activity. Give each student an eyedropper and a penny. Ask them to predict how many drops of water will fit on the penny without spilling. Distribute dishes of water and have them find out.

After the students have a chance to observe the surface tension of the water on a penny, ask them to put drops of water on a penny again. Then have them "break" the surface tension of the water on the penny by adding a drop of soap solution.



- To demonstrate the effect of soap on surface tension, carefully add one drop of soap to the very full glass of water. This should "break" the surface tension of the water, causing it to overflow. Explain that soap decreases the surface tension of water to about one-third of what it usually is: just right for making bubbles.

Discussing the Problem of Evaporation

1. Point out that another problem with using water to blow bubbles is that water evaporates very rapidly. When the water evaporates, the bubble wall is broken. This problem is not limited to the use of pure water since most soap bubble solutions contain water.

2. Explain that scientists have devised a way to deal with the problem of evaporation: adding a substance to the bubble solution to keep water from evaporating. Substances that have water-holding properties are referred to as ***hygroscopic***. Glycerin is a hygroscopic liquid that is typically added to bubble solutions. Glycerin forms a weak chemical bond with water that delays evaporation.

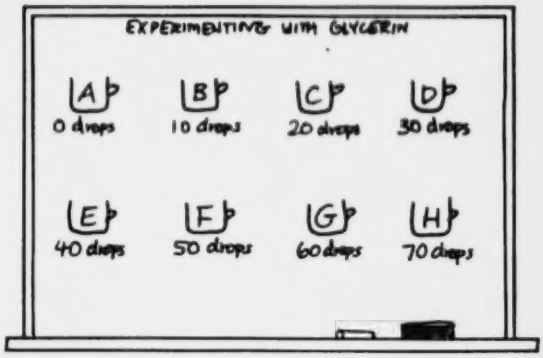
Planning the Experiment

1. Tell your students that their challenge is to determine what effect the *amount* of glycerin in a bubble solution has on the *size* of the bubbles formed.

2. Ask the students for their ideas on ways of designing the experiment so it is a fair comparison. Use the following questions to guide the group in determining the test procedure they'd like to use.

- What is the test variable? [Amount of glycerin.]
- What variables must be kept the same or "controlled"?

3. Present a plan for varying the amount of glycerin while keeping the amount of water and dishwashing liquid the same. Draw eight cups on the chalkboard. Tell the class that each test formula will start with one cup of bubble solution made without glycerin. Formula A will have 0 drops of glycerin added to it. Formula B will have 10 drops of glycerin added to it, and so on up to Formula H which will have 70 drops of glycerin added. On the chalkboard, record the letter of the formula and the number of glycerin drops in each "cup."



4. Ask the students if they have any expectations about the experiment. How much glycerin do they think will make the biggest bubbles?

Experimenting

1. Assign pairs of students to test the formulas. Have them apply the same method for measuring bubble size used in Activity 2: Comparing Bubble Solutions, as explained on pages 12 and 13.

2. As students finish testing one formula, have them swap work stations and test other formulas. For best results, each formula should be tested by at least four different groups.

Graphing the Results

1. Ask your students to gather around the chalkboard. Record the students' averages under the formula names written across the top of the board. Calculate the grand average for each formula.

2. Ask your students to graph the results of all experiments on a graphing sheet (master included). Does the graph show an optimum amount of glycerin for making the biggest bubbles?

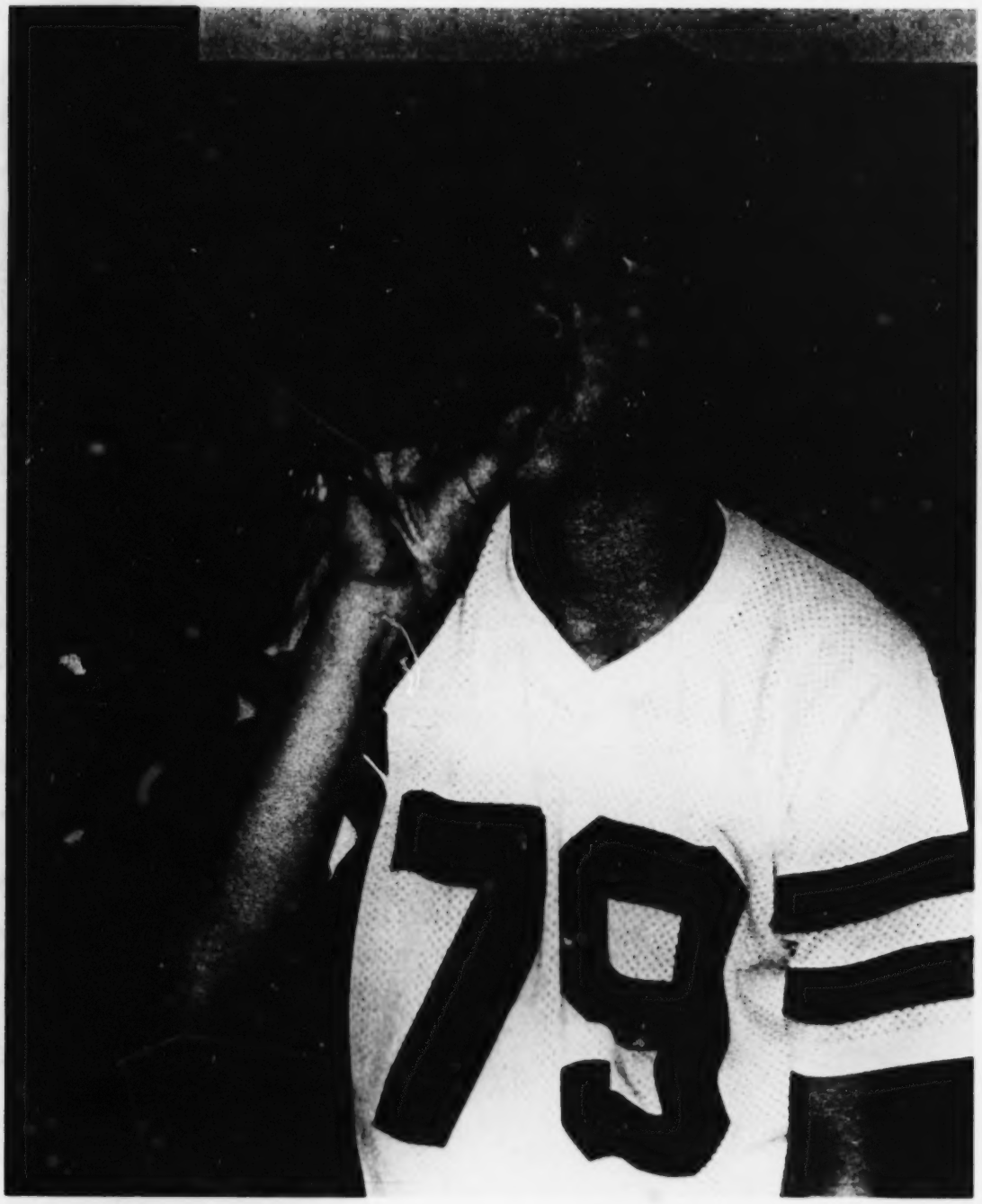
Note: Sometimes student data has so much variation that it is difficult to identify an optimum amount of glycerin. If so, have your group identify a broader range for the desirable amount of glycerin. Ask them how they would improve the experiment in order to pinpoint more exactly the optimum amount of glycerin.

3. You may want to ask your students if they were surprised by the results. Many students assume at first that the more glycerin used, the bigger the bubbles will be. As this experiment demonstrates, that is not the case.

Going Further

1. Sugar is another hygroscopic substance. Challenge your students to repeat their experiments using sugar instead of glycerin. Compare the results of the two experiments. Which is better for making big bubbles, sugar or glycerin?

2. Give your students the open-ended challenge of developing their own ideal bubble solutions. Remind them to vary only one ingredient at a time as they experiment, and to keep a careful record of what they do.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EXPERIMENTING WITH GLYCERIN

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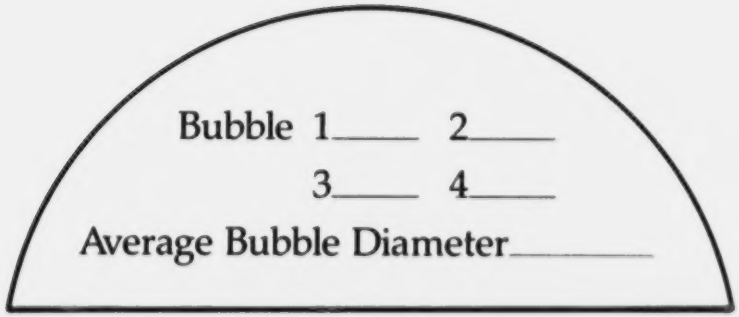
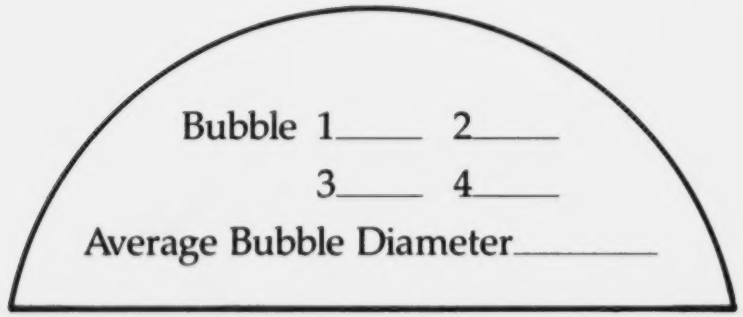


Number of Drops of Glycerin____



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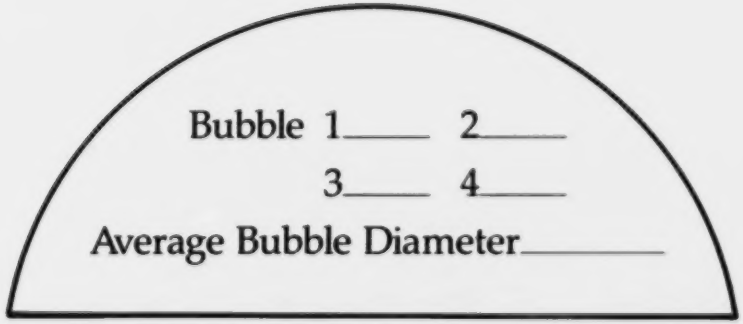

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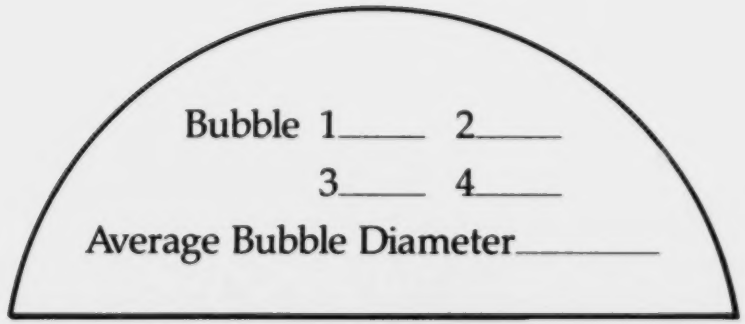

Number of Drops of Glycerin____

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LHS—Great Explorations in Math and Science: *Bubble-ology*

GRAPHING SHEET

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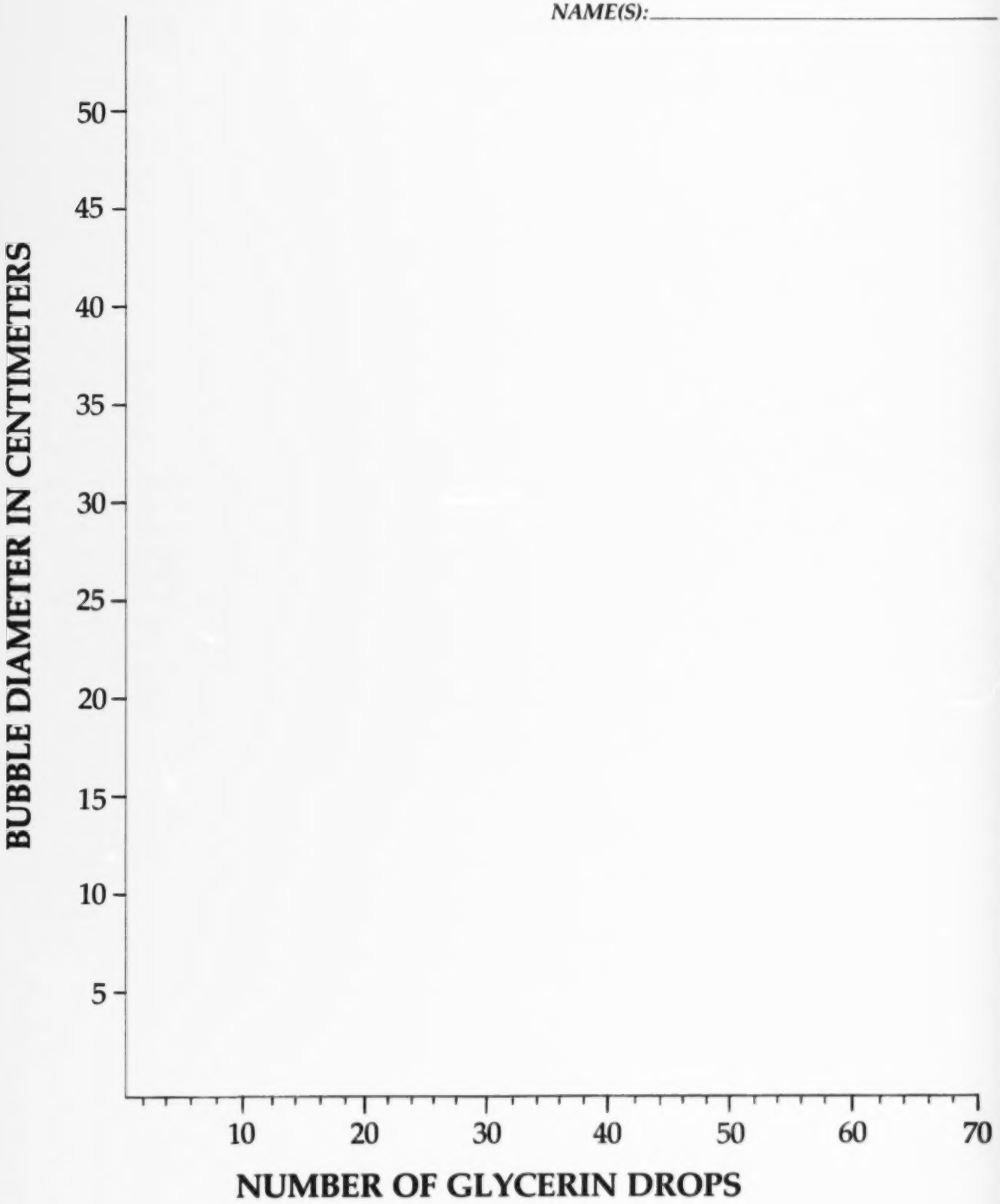

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Activity 4: Bernoulli's Bubbles

Introduction

For centuries, scientists have been interested in finding ways to make things fly. From the ancient Chinese, who made large kite-gliders, to Leonardo da Vinci, who designed a machine with flapping wings, humanity pursued the dream of flight.

In the 18th century, a scientist named Daniel Bernoulli discovered a scientific principle that now carries his name. Although he was working with liquids, the principle can be applied in many ways, and it became the basis for airplane flight many years after its discovery.

In this activity, you'll introduce aerodynamics to your students by challenging them to devise the best ways to keep a bubble aloft. In this fun context, you'll teach Bernoulli's principle and help explain how airplanes fly.

What You Need

For preparation and cleanup:

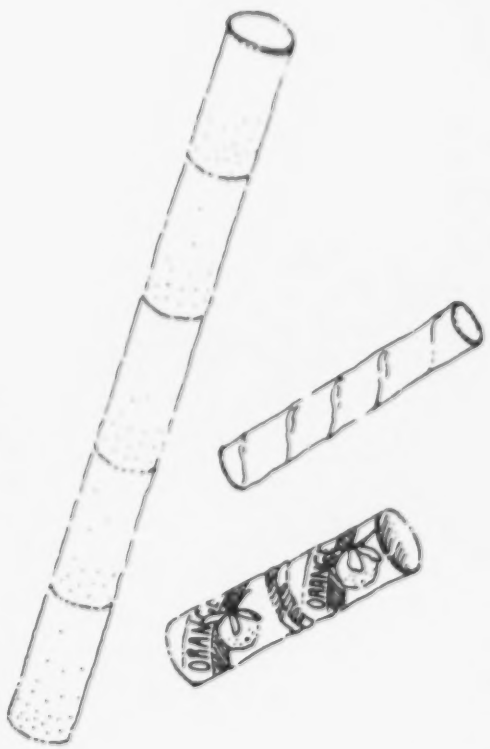
- ☐ newspapers to put under containers of bubble solution
- ☐ 8 oz. (240 ml) dishwashing liquid
- ☐ water
- ☐ 1 measuring cup or graduated cylinder
- ☐ 1 eyedropper
- ☐ 1 one-gallon container for mixing bubble solution
- ☐ glycerin (optional)

For each group of 4–6 students:

- ☐ 1 pint-sized container (such as a cottage cheese container) for holding bubble solution

For each student:

- ☐ 1 tube (about 7"–11" in length, 1"–2" in diameter—such as: plastic golf club covers cut in 7" lengths, cardboard paper towel rolls, polyvinylchloride pipes, or two small cans taped end-to-end with lids removed)
- ☐ 1 3"x5" index card



Getting Ready

1. Prepare one gallon of bubble solution:
   1 cup (240 ml) dishwashing liquid
   50–60 drops glycerin (optional)
   1 gallon water (3.8 liters)

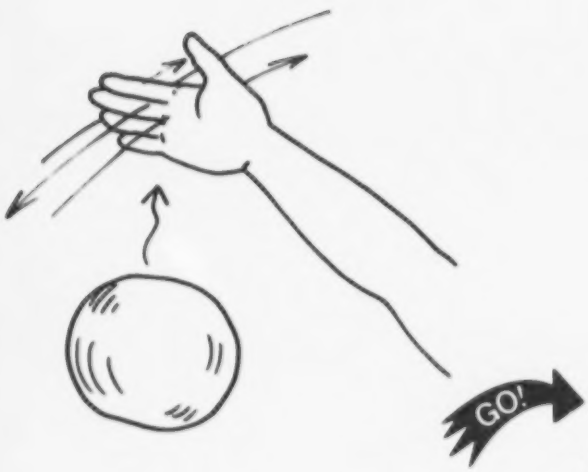
2. Place small containers of the bubble solution on newspaper, in various locations around the room.

3. Spend five minutes practicing the technique of keeping a bubble in the air by waving your hand back and forth over it. You will want to master this technique before you demonstrate it for the students.

Hints:

- If you have trouble detaching the bubble from the bubble-blower, try flicking your wrist toward you so the end of your bubble-blower points upward.

- If you are having trouble keeping your bubble in the air, try this: dip your blower in solution; blow and release one bubble; blow and release a second bubble. Try keeping the second bubble up—"second bubbles" are lighter because they are made with less bubble solution.



Exploring

1. Challenge your students to devise ways to keep a bubble from hitting the ground, without touching it with their hands or with any other objects. As they find methods that work, encourage them to experiment with other approaches. If students have difficulty detaching the bubbles from their bubble-blowers, show them how to flick their wrists toward themselves so the end of the bubble-blower points upward.

2. Have the students set their bubble-blowers aside and sit where they can see the chalkboard. As a group, make two lists: methods that worked, and those that didn't work.

Explaining

1. Present the brief historical perspective given in the first paragraph of this activity. Explain that the ***Bernoulli principle*** states that the faster air flows, the less pressure it exerts.

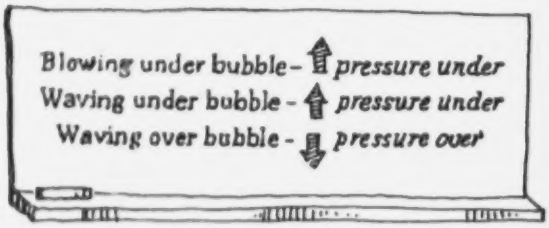
2. Draw a diagram of an airplane and an airplane wing on the chalkboard. Point out that as air hits the wings of a plane, some of it has to go over them and some of it has to go underneath. Scientists have discovered that regardless of whether the air goes over or under, it arrives at the other side of the wing at the same instant. The same holds true for the air that goes over and under the body of the plane. Ask your students the following questions:

- Which air has to travel faster to make it to the other side; the air that goes over the wing or under the wing? [The air that goes over the wing: it has farther to travel in the same time period.]

- What does the Bernoulli principle say about faster moving air? [It exerts less pressure.]

- If there is greater pressure pushing up from under the airplane, what will happen? [The airplane will go up!]

3. Explain that the force pushing upward is called ***dynamic lift***. You might add that other engineering principles are brought into play to provide additional lift.



4. Summarize by stating that there are two approaches to keeping an object aloft: increasing the pressure under it, or decreasing the pressure over it. Ask the group to examine, one by one, the list of methods that worked and to decide whether each method worked by increasing the pressure under the bubble, or by decreasing the pressure over it.

Applying the Principle

1. Show how to use Bernoulli's principle to decrease the pressure over a bubble. Demonstrate how you can keep a bubble in the air by waving your hand back and forth over it. Waving your hand over the bubble causes the air to move faster; faster moving air exerts less pressure. The faster you wave, the higher the bubble goes.

2. Challenge your students to use Bernoulli's principle to keep their bubbles aloft. Make sure you allow enough time for all students to be successful. If students have difficulty, give them the hint about using the second bubble described on page 30 in the "Getting Ready" section.

3. After the students have time to try the hand-waving method, distribute index cards and invite them to wave the cards to further demonstrate Bernoulli's principle.

Going Further

1. Set up a series of short bubble obstacle courses, including challenging features such as steps, curves, corners, and a hoop. After your students have had time to try maneuvering their bubbles through the course, lead a discussion: What was the most difficult situation? What refinements did they develop to increase the amount of distance the bubbles were able to travel through the course?

Propelling a bubble through an obstacle course requires not only that the bubble stay aloft, but also that it move in a forward direction. If students don't figure this out for themselves, suggest that they work in pairs, having one person wave over the bubble and the other person wave behind the bubble.

2. Have your students research Daniel Bernoulli and the history of flight.

3. Make or obtain posters of airplanes and airplane wings, and post them around the classroom. Ask students to explain how the Bernoulli principle is incorporated into the design of each plane.

4. Challenge students to use bubbles to detect air flow patterns in a room or outdoors. In which direction is the wind blowing? Does that air vent blow air into the room? What happens to currents near the building? Can they observe any whirlpool movement? Provide them with a map or help them create one. Discuss techniques they can use to indicate direction of air flow on their maps.

Activity 5: Predict-A-Pop

Introduction

Blow a soap bubble. Can you tell when it will pop? You and your students may have already discovered that color is one important clue. It's interesting that color should be a key to predicting bubble survival, since we usually think of color as a mere surface decoration. But actually the colors of a soap bubble are produced by a complex interaction between light and matter called ***interference***.

This activity is a playful introduction to interference, an important phenomenon in the history of physics and in modern industry. Your students will enjoy discovering how to count down the last few seconds of a bubble's existence.. 3..2..1... POP!!

What You Need

For preparation and cleanup:

- ☐ 8 oz. (240 ml) dishwashing liquid
- ☐ water
- ☐ 1 measuring cup or graduated cylinder
- ☐ 1 eyedropper
- ☐ 1 one-gallon container for mixing bubble solution
- ☐ several rolls of masking tape
- ☐ glycerin (optional)

For each pair of students:

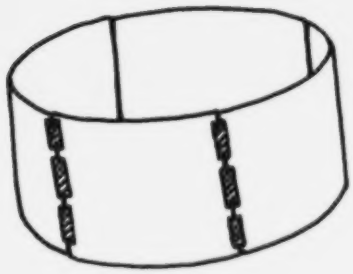
- ☐ 1 pint-sized container for holding bubble solution
- ☐ 2 plastic drinking straws
- ☐ 6 8½"x11" sheets of white paper
- ☐ 1 flat, dark surface about 18" (45 cm) in diameter

  or
- ☐ 1 cafeteria tray and black construction paper to cover the tray

Getting Ready

1. Prepare one gallon of bubble solution:
   1 cup (240 ml) dishwashing liquid
   50–60 drops glycerin (optional)
   1 gallon water (3.8 liters)

2. Pour the bubble solution into the small containers. Place the containers in a central location along with straws, white paper, and masking tape.



3. Clear off a flat, dark surface (about 18" [45 cm] in diameter) for each pair of students.

4. Prepare one "white collar" by taping four sheets of white paper together so they form a cylinder 8½" high. The white collar reduces air currents and reflects light onto the bubble so its colors can be seen clearly.

Observing Colors

1. Gather the students around you. Blow a bubble dome as follows:

   a. Pour about ⅓ cup of soap solution on the surface of the table or tray, and use your hand to wet an area about 18" (45 cm) in diameter.

   b. Place the white collar around the soapy area.

   c. Dip a straw into the soap solution.

   d. With the straw just touching the surface of the table, gently blow through the straw to form a bubble dome.

   e. Remove the straw.

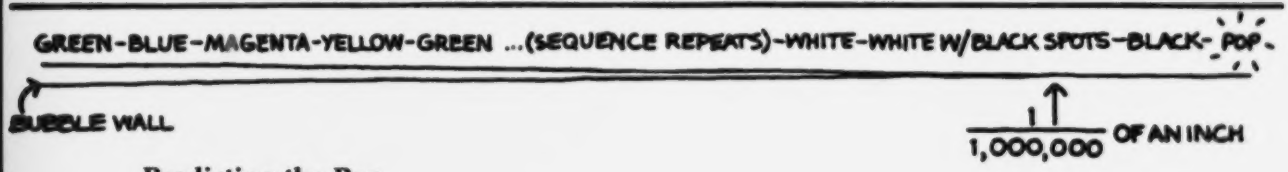
If your students have difficulty seeing the colors on top of the bubble, suggest that they position a piece of white paper so that it will reflect more light onto the top of the bubble.

2. Explain that the challenge for the day is to use color to recognize the moment just before a bubble pops. Instruct each pair of students to start by making a collar, blowing a bubble dome, and observing the changing colors *on top of the bubble.* Tell them to record the sequence of colors they see for four or five bubbles.

Reporting Results

Have the students leave their materials and form a circle in view of the chalkboard. As several of the teams report, record their findings on the board. The students will probably discover a repeating sequence something like this: green to blue to magenta to yellow to green... (sequence repeats more than once)... and finally white to white with black spots to black—POP!! (The spots are actually transparent but because the background is black, they appear black.) Explain that the colors on the surface of a bubble change as the bubble becomes thinner and thinner.

Not all students will see this pattern because air currents may interfere with the gradual thinning of the top of the bubble, interrupting the usual color sequence. Write the typical color sequence on the board and draw the decreasing bubble wall underneath it. (See diagram.) Explain that in cases where there are absolutely no air disturbances, such as a bell jar, this is the pattern scientists have reported seeing. Ask the students if they notice any aspects of the typical pattern in their data.



Predicting the Pop

Now challenge the students to apply what they learned to invent a method for counting down, to the second, when their bubbles will pop. Here are strategies some students have used:

- timing how long a period elapses between the appearance of the first white color on the bubble and when it pops;
- noticing how far down the side of the bubble the transparent or "black" area extends before the bubble pops;
- noticing how long before the "pop" a bubble loses its reflective properties.

Let your students discover their own approaches before mentioning strategies used by other students.

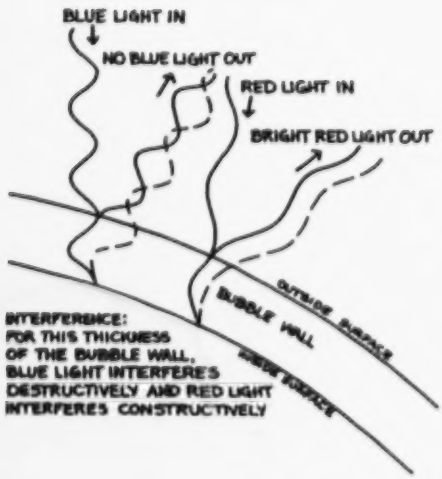
Explaining the Phenomenon

The following explanations are written for the teacher. After your students have some success in predicting when a bubble will pop, you may want to discuss these explanations with them. Use your judgment about how much to present to your students. Typically, the concept of interference is first presented in high school physics courses.

1. Where do the colors in a bubble come from?

The colors in a bubble come from the reflection of white light shining on the bubble. White light contains waves of all different colors. The length of a wave, from crest to crest, determines its color. When light bounces off a bubble, some of each wave is reflected from the outer surface of the bubble wall, and some passes through to be reflected by the inner surface.

Interference refers to what happens when two waves pass through the same region of space at the same time. For example, when two rocks are thrown into a lake near each other, the two sets of circular waves *interfere* with one another. In some places, where the crest of one wave meets the crest of another, the motion of the water is increased. In other places, the crest of one wave meets the trough of another and there is little or no movement. The same basic process holds true for other wave motion, including sound waves and light waves.



When the thickness of the bubble wall is such that the two reflected parts of the wave of light leave the bubble in step, crest to crest (as illustrated by red light in the diagram), that color appears brighter ***(constructive interference).*** Some colors of light will emerge crest to trough (as illustrated by blue light in the diagram) and will cancel each other ***(destructive interference):*** those colors will not be seen. As the wall gets thinner, the colors that interfere constructively and destructively will also change.

2. Why does the bubble appear white with growing black (or transparent) spots just before the bubble pops?

When the wall is less than a quarter wavelength thick for any color, none of the colors are completely cancelled—so the bubble appears white. Black spots appear when the wall is super-thin (about one millionth of an inch). This occurs because light reflected from the top surface is always reversed (all troughs become crests) but the light reflected from the back surface is not reversed. Thus, when the wall is super-thin, every light wave will cancel itself.

Cleanup

1. If dark table surfaces were used:

   a. First use a squeegie or paper towels to remove excess bubble solution from the table surface. **Do not add water.**
   b. Then sprinkle vinegar on the area to cut the soap film. Wipe dry with paper towels.
   c. Repeat once more if surface still retains soap film.

2. If trays with black construction paper were used:

   a. Discard soggy black paper.
   b. Pour the bubble solution remaining on the tray down the sink or into a spare container. (**Note:** black dye from the construction paper will have leached into the soap solution, causing it to appear dark in color.)
   c. Rinse off the tray.

Going Further

1. Assign students to look up the name Thomas Young and the concept of ***interference***. They will find out about: (1) the controversy surrounding wave and particle theories of light; and (2) modern applications of interference phenomena, such as anti-reflection coatings on binoculars.

2. Have your students begin a collection of materials that exhibit the phenomenon of interference: abalone shells, peacock feathers, some sunglasses, etc.

Activity 6: Longer Lasting Bubbles

Introduction

Blow a bubble that will last for ten minutes... twenty minutes... or over an hour! Yes, it's possible! In 1917, Sir Thomas Dewar made a bubble that lasted 108 days. Since then, Eiffel Plasterer, a physicist who has been blowing bubbles for close to sixty years, blew a bubble that lasted for 340 days! Present this challenge to your students, and let them apply what they've learned about bubbles. This open-ended experiment serves as an excellent culmination to a unit on bubble science.

Note: Bubbles will often last longer than a single class period. If possible, plan on conducting this experiment in the morning, so students can check later in the day to see if their bubbles are still "alive."

What You Need

For preparation and cleanup:

- ☐ 8 oz. (240 ml) dishwashing liquid
- ☐ water
- ☐ 1 measuring cup or graduated cylinder
- ☐ 1 eyedropper
- ☐ 1 one-gallon container for mixing bubble solution
- ☐ glycerin (optional)

For each pair of students:

- ☐ 2 plastic drinking straws
- ☐ 1 pint-sized container (such as a cottage cheese container) for holding bubble solution
- ☐ 1 "Long-Lived Bubbles" data sheet (master included, page 44)
- ☐ 1 pencil

For the class:

Various materials such as:

- ☐ containers to blow bubbles in: clear screw-top jars—as large as possible, plastic dishpans, styrofoam egg cartons, etc.
- ☐ materials to cover containers: clear plexiglass sheets, plastic wrap, cafeteria trays, cheese cloth, aluminum foil
- ☐ humidifying materials: turkey basters, sponges, water spray bottles
- ☐ solution additives: sugar, glycerin, corn syrup, white glue, rubbing alcohol, extra dishwashing liquid
- ☐ volumetric measuring devices: measuring cups, measuring spoons, graduated cylinders, eyedroppers
- ☐ any other items you and your students deem appropriate

Getting Ready

1. Prepare one gallon of bubble solution:
   1 cup (240 ml) dishwashing liquid
   50–60 drops glycerin (optional)
   1 gallon water (3.8 liters)

2. Make one copy of the "Long-Lived Bubbles" data sheet for each pair of students.

3. Place all materials on a centrally located table.

Introducing the Challenge

1. Present your students with the problem: How long can you make a bubble last? Remind them that variables are things that can be changed. Ask them which variables might affect the life span of a bubble [humidity, air currents, solution additives]. Ask for their ideas of ways to change these variables in order to increase the life span of their bubble [increase the humidity of the air around the bubble, decrease a bubble's water loss by adding a hygroscopic substance to the bubble solution, keep a bubble in an enclosed container to reduce air currents, etc.].

2. Tell your students they will have two class sessions to work on the challenge. They can use any of the materials you've collected, and they may bring in additional materials from home.

Experimenting

Give each pair of students a data sheet. Tell them to use the data sheets to keep track of what they do and how long their bubbles last. Students should keep data sheets right next to their bubbles so ongoing observations can be recorded easily (e.g. 10:35—starting time. 10:45—bubble's alive. 10:55—alive. 11:55—alive, thinning on top, misted container with water, etc.). Because bubbles often outlive a single class period and occasionally last for several days, sometimes the teacher or other students will need to note whether a bubble is still "alive." Having the data sheet right there makes it easy for others to do this. School custodians have even been known to make data entries!

Reporting Results

Gather the group into a circle. Invite teams to report their results. Help the group to summarize.

- Which variables were most important in extending the life of a bubble?
- What strategies were most effective in altering those variables?

LONG-LIVED BUBBLES

NAME(S): _____

Describe the conditions of your experiment:	How long did the bubble last?

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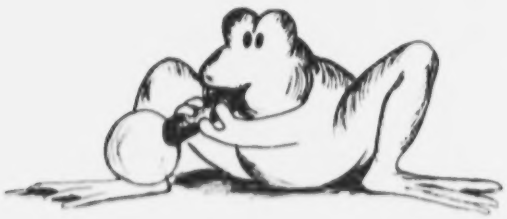
Resources

Boys, C.V. *Soap Bubbles; Their Colors and Forces Which Mold Them*, Dover Publications, 1959.
This classic bubble science text is for those who want to go right to "the source."

The Exploratorium, *Films, Foams, and Fizz*, 1983.
A very readable pamphlet containing explanations of bubbles and bubble phenomena.

Zubrowski, Bernie, *Bubbles*, Little Brown and Co., 1979. Though illustrated for elementary age children, this book is filled with good activities and questions for all grade levels.



Summary Outlines

Activity 1: Bubble Technology

Getting Ready Before the Activity

1. Assemble materials.
2. Make bubble solution.
3. Cover tables with newspaper.
4. Fill containers with bubble solution and set on tables.
5. Place bubble-maker materials on tables.
6. Clear two table surfaces so students can classify materials.

Presenting the Challenge

1. Lead short discussion about blowing bubbles. Explain that students will discover which objects can be used to blow bubbles and what kinds of bubbles the objects make.
2. Point out objects they may test.
3. After testing each object they should place it on the "works" table or on the "doesn't work" table.
4. Write "small" on one side of the board and "large" on the opposite side. Have students write the name of each object that "works" on the board in order according to the bubble size produced.

Experimenting

1. Have students experiment with objects.
2. Circulate among students, posing questions.

Drawing Conclusions

1. Gather students around the chalkboard. Ask:
   - What's the same about all working bubble-makers?
   - What objects didn't work?
   - What were these objects lacking?
   - What strategies did you use to make something work?

2. Discuss which bubble-makers made large bubbles, which made small bubbles, and what characteristics those making larger bubbles have in common.
3. Explain that **technology** involves the use of science to create something practical. As a homework assignment, ask them to use what they've discovered about bubble-makers to create a specialized bubble-maker.

Activity 2: Comparing Bubble Solutions

Getting Ready Before the Activity

1. Assemble materials.
2. Duplicate one data sheet for each pair of students.
3. Label bubble solution containers with brand name.
4. Make three different bubble solutions (from three different brands of dishwashing liquid).
5. Fill labeled containers with bubble solution.
6. Clear one work station for each pair of students. Place a container of bubble solution and a meter stick at each station.

Introducing the Activity

1. Explain that students will compare brands of dishwashing liquids to find out which solution makes the biggest bubbles. Ask how they might do this.
2. Introduce the following procedure:
   a. Wet the table surface with bubble solution.
   b. Dip a straw into the bubble solution.
   c. Hold the straw near the soapy table surface and gently blow to form a bubble dome. Continue blowing until the bubble pops.
   d. Measure the diameter of the ring of soap suds left by the bubble dome.

Experimenting

1. Have students work in pairs to measure four bubbles per brand, record the bubble diameters on the data sheet, and calculate the average bubble diameter for each brand.
2. Respond to questions of "Is this fair?" by reminding them that they are the scientists and they must make sure that they treat each brand in exactly the same way.

Analyzing Results

1. Reconvene the class. Write the names of the brands on the chalkboard and have your students record their averages for each brand. Have the students calculate the grand average.
2. Make a bar chart of the results on the chalkboard. Rank the brands from biggest to smallest bubble-maker.
3. Ask if the test was a fair test. Introduce concept of **variable.** Explain concept of **controlled experiment.**
4. Ask and discuss why one brand might make bigger bubbles than another.

Activity 3: The Chemistry of Bigger Bubbles

Getting Ready Before the Activity

1. Assemble materials.
2. Duplicate one data sheet and one graphing sheet for each pair of students.
3. Make bubble solution.
4. Clear one work station for each pair of students.
5. Place demonstration materials on table or desk.
6. Make solutions "A" through "H."
7. Place all solutions and materials in centrally located area.

Observing Surface Tension

1. Lead a short discussion about substances that form bubbles.
2. Perform the following demonstration:
   a. Have the group squat around the demonstration table.
   b. Fill a glass to the top with water. Keep adding water drop by drop until the surface of the water is higher than the glass.

c. Tell students that they are observing the phenomenon of **surface tension,** and explain the concept. Tell students that surface tension prevents the water in the cup from spilling, and keeps bubbles from forming in many substances.
d. Demonstrate how a drop of bubble solution reduces surface tension. Explain that the surface tension in soapy water is low enough to allow bubbles to form easily.

Discussing the Problem of Evaporation

1. Explain that evaporation also affects the formation of bubbles.
2. Explain that substances with water-holding properties (**hygroscopic substances**) will reduce evaporation. Glycerin is a hygroscopic substance that slows the evaporation of water in bubble solution.

Planning the Experiment

1. Tell the class they will determine what effect the amount of glycerin in a bubble solution has on the size of the bubbles formed.
2. Help students plan a more controlled version of the experiment they used to compare brands of dishwashing liquid.
3. Describe the contents of Formulas "A" through "H" (1 cup bubble solution, 0 drops glycerin; 1 cup bubble solution, 10 drops glycerin, and so on). Ask students to predict which solution will make the biggest bubbles.

Experimenting

1. Assign pairs of students to test the solutions, using the same method they used in Activity 2, with whatever improvements the class decided to make.
2. Have students swap work stations and test additional formulas until each formula has been tested by at least 4 student teams.

Graphing the Results

1. Record the averages on the board. Calculate the grand average for each formula.
2. Ask your students to graph the results of all experiments on the graphing sheet. What is the optimum amount of glycerin for making the biggest bubbles?
3. Ask if anyone was surprised by the results.

Activity 4: Bernoulli's Bubbles

Getting Ready Before the Activity

1. Assemble materials.
2. Make bubble solution.
3. Fill containers with bubble solution and place them on squares of newspaper in various locations.
4. Spend five minutes practicing the technique of keeping a bubble aloft by waving your hand back and forth over it.

Exploring

1. Challenge students to devise ways to keep a bubble from hitting the ground without touching the bubble.
2. Have students set their bubble-blowers aside. Make two lists: methods that work, and those that do not.

Explaining

1. Provide a brief historical perspective on human pursuit of flight, and the Bernoulli principle. Explain that the Bernoulli principle states that the faster air flows, the less pressure it exerts.
2. Draw a diagram of an airplane and an airplane wing on the board and explain how the Bernoulli principle applies to airplanes.
3. Tell students that the force pushing upward is called **dynamic lift.**
4. Explain that there are two ways to keep an object aloft: increase the pressure under it, or decrease the pressure over it. Have the class examine the list of methods that kept a bubble aloft, and discuss how each method worked.

Applying the Principle

1. Demonstrate how to use Bernoulli's principle to decrease the pressure over a bubble.
2. Challenge your students to use Bernoulli's principle to keep their bubbles aloft.
3. Distribute index cards for students to use in waving over their bubbles.

Activity 5: Predict-A-Pop

Getting Ready Before the Activity

1. Assemble materials.
2. Make bubble solution.
3. Fill containers with bubble solution and place in central location with straws, white paper, and masking tape.
4. Clear a work surface for each group of 2–4 students. If the surface is not dark, line a cafeteria tray with black construction paper.
5. Prepare one "white collar."

Observing Colors

1. Demonstrate the procedure:
   a. Pour bubble solution on the dark surface or on the tray lined with construction paper.
   b. Place the white collar around the soapy area.
   c. Dip a straw into the soap solution.
   d. Hold the straw near the soapy table surface and gently blow to form a bubble dome.
   e. Remove the straw.
2. Instruct each group of 2–4 students to make a collar, blow a bubble dome, and observe the changing colors on top of the bubble. Tell them to record the sequence of colors they see for 4 or 5 bubbles.

Reporting Results

1. Assemble the students near the chalkboard. Record the findings of several teams on the board. Explain that the colors on the surface of a bubble change as the bubble becomes thinner and thinner.
2. A typical sequence that scientists have noticed is: green—blue—magenta—yellow—(sequence repeats more than once)—and finally white—white with black spots—black—POP! Explain that not all students will see this pattern because air currents interfere with the thinning of the bubble.
3. Draw a diagram of the decreasing bubble wall under a listing of the typical color sequence. Ask students if they notice any aspects of the typical pattern in their data.

Predicting the Pop
Challenge students to apply what they have learned to invent a method for counting down, to the second, when their bubbles will pop.

Explaining the Phenomenon (Optional)

1. Where do the colors in a bubble come from?
   a. The colors come from the reflection of white light.
   b. White light contains waves of all different colors.
   c. The length of a wave, from crest to crest, determines its color.
   d. When light bounces off a bubble, some of each wave is reflected from the outer surface of the bubble wall, and some passes through to be reflected by the inner surface.
   e. **Interference** refers to what happens when two waves pass through the same region of space at the same time.
   f. When the thickness is such that reflected waves leave crest to crest, that color appears brighter (**constructive interference**).
   g. When reflected waves leave crest to trough, that color will cancel (**destructive interference**).
   h. As the bubble wall gets thinner and thinner, the colors that interfere constructively and destructively also change.
2. Why does the bubble appear white with growing black spots just before the bubble pops?
   a. When the wall is less than a quarter wavelength thick for any color, none of the colors are cancelled completely, so the bubble appears white.
   b. Black spots appear when all colors are cancelled.

Activity 6: Longer Lasting Bubbles

Getting Ready Before the Activity

1. Assemble the materials.
2. Make the bubble solution.
3. Duplicate one data sheet for each pair of students.
4. Place all materials on a centrally located table.

Introducing the Challenge

1. How long can you make a bubble last?
   a. Which variables might affect the life span of a bubble?
   b. How could you change those variables to increase the life span of a bubble?
2. Announce that students have two sessions to work on this challenge, and may want to bring additional materials from home.

Experimenting

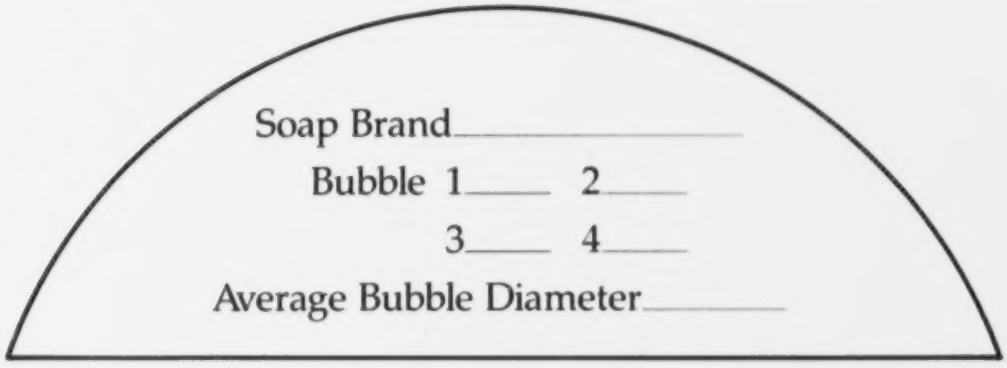
1. Distribute a data sheet to each pair of students.
2. Explain how to use the sheet to record results.

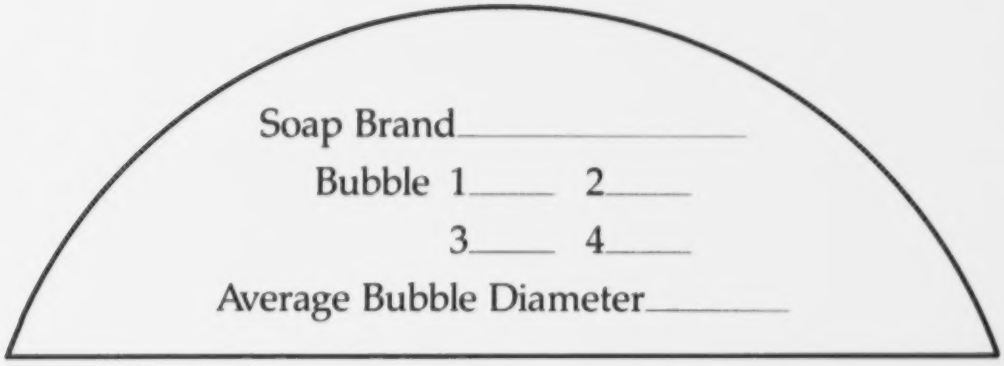
Reporting Results

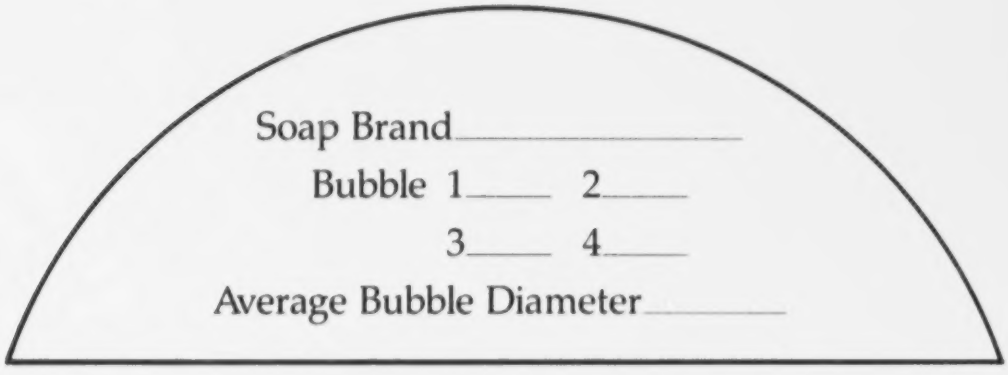
1. Invite teams to report their results.
2. Help the group summarize which variables were most important in extending the life of a bubble and what strategies were most effective in altering those variables.

BUBBLE SOLUTIONS

NAME(S): _____







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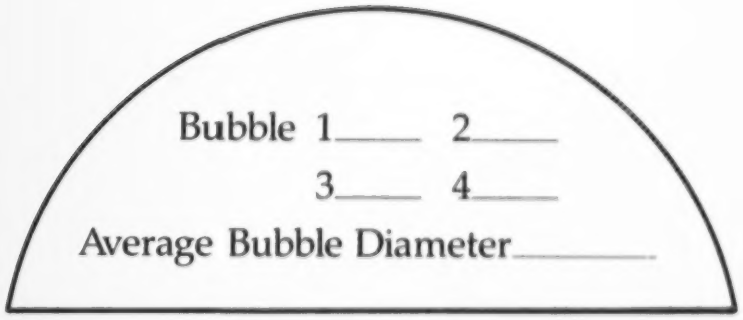
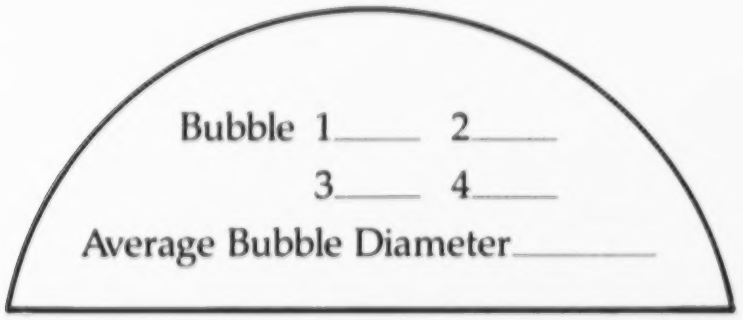
WHICH SOAP BRAND HAD THE BIGGEST AVERAGE BUBBLE DIAMETER?

EXPERIMENTING WITH GLYCERIN

NAME(S): _____



Number of Drops of Glycerin____



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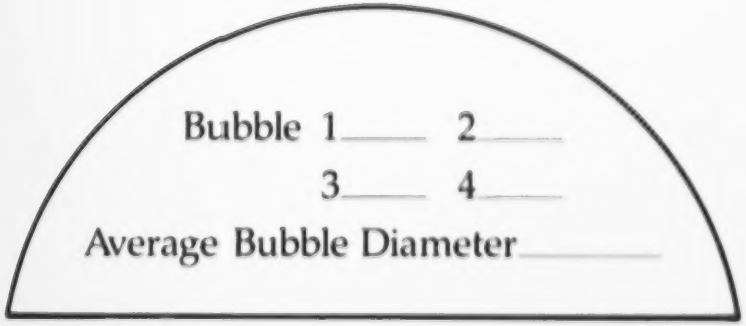
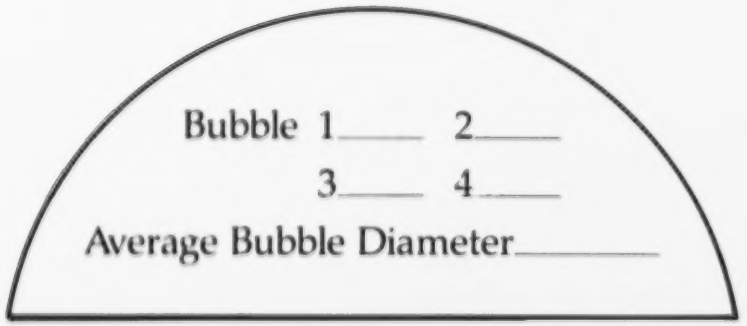


Number of Drops of Glycerin____



Number of Drops of Glycerin____

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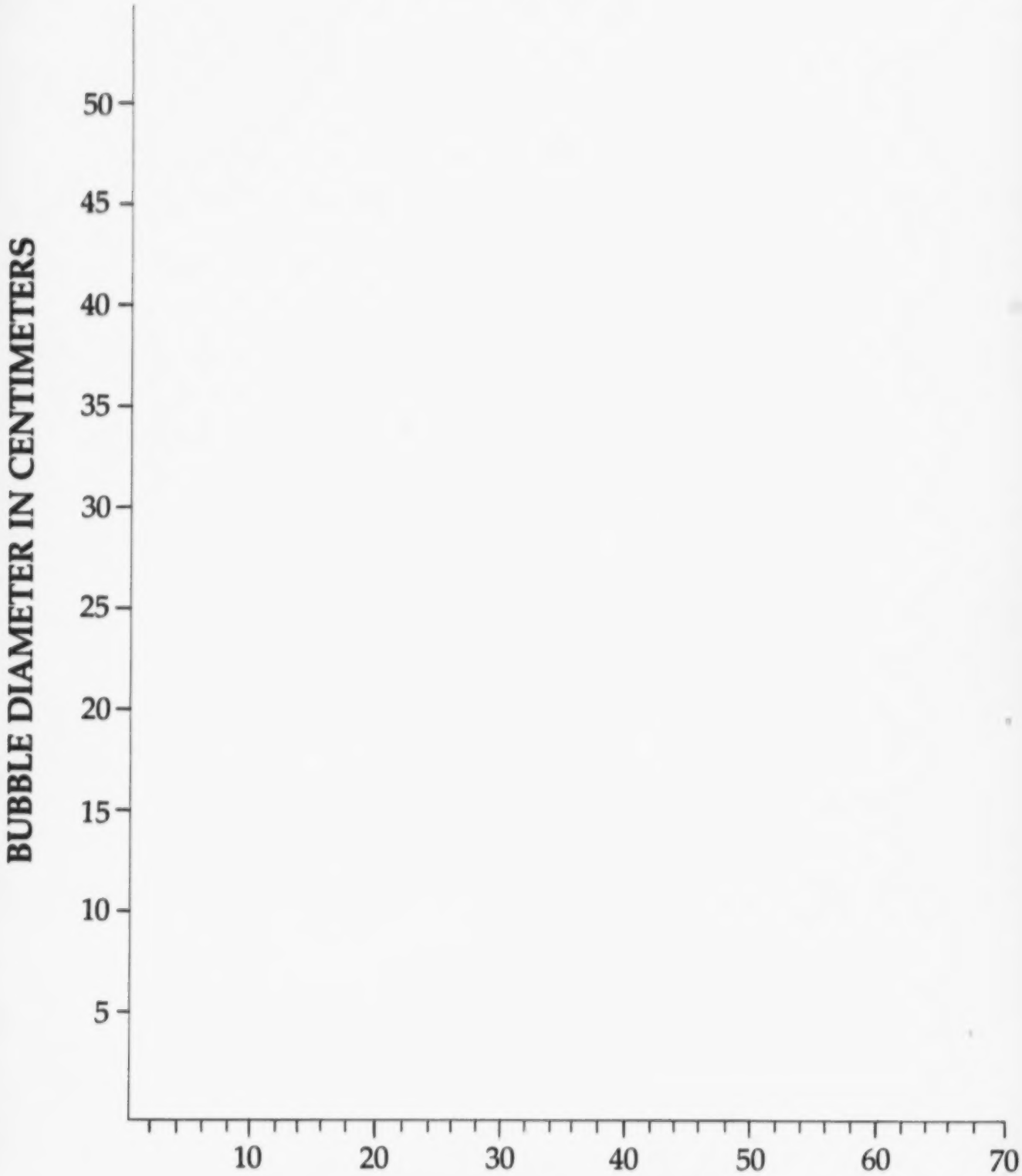
GRAPHING SHEET

*NAME(S)*_____



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NAME(S)_____

LONG-LIVED BUBBLES

Describe the conditions of your experiment:	How long did the bubble last?

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